R E METROLOGY

NAVSHIPS 91842
T.O. No. 16-30URM43-15

INSTRUCTION BOOK

for

RADIO FREQUENCY WATTMETER AN/URM-43A

ELECTRO IMPULSE LABORATORY, INC.
RED BANK, NEW JERSEY

BUREAU OF SHIPS NAVY DEPARTMENT

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BUREAU OF SHIPS
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IN REPLY REFER TO

Code 993-100
28 December 1953

From: Chief, Bureau of Ships
To: All Activities Concerned with the Installation, Operation and Maintenance of the Subject Equipment

Subj: Instruction Book for RF Wattmeter AN/URM-43A, NAVSHIPS 91842

1. This is the instruction book for the subject equipment and is in effect upon receipt.

2. When superseded by a later edition, this publication shall be destroyed.

3. Extracts from this publication may be made to facilitate the preparation of other Department of Defense Publications.

4. All Navy requests for NAVSHIPS Electronics publications should be directed to the nearest District Publications and Printing Office. When changes or revised books are distributed, notice will be included in the Bureau of Ships Journal and in the Index of Bureau of Ships General and Electronics Publications, NAVSHIPS 250-020.

W. D. LEGGETT, JR.
Chief of Bureau

RECORD OF CORRECTIONS MADE

Change No.	Date	Signature of Officer Making Correction

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SECTION 1
GENERAL DESCRIPTION

1. SCOPE OF MANUAL

This instruction book covers the description, theory, operation, and maintenance of RF Wattmeter AN/URM-43A.

2. PURPOSE OF EQUIPMENT

a. The AN/URM-43A equipment, of which the basic operating unit is the RF Wattmeter ME-11A/U, is designed, to measure output power and facilitate tuning of transmitters falling within the following limits:

Frequency	30 to 600 mc/sec.
Power	2 to 60 watts (Ranges are 0-15 and 0-60 watts)
Output Circuit	Coaxial. 51.5 ohms Nominal
Type of Modulation	CW, AM, FM or Television Type Signals. (Not designed for use on pulsed power similar to radar).

b. It can be used to measure RF power from any source within its rating.

c. It may be used as a Dummy Load of 51.5 ohms up to 60 watts.

3. DESCRIPTION

(See figure 1-1.)

a. The equipment included with this unit comprises transit case CY-1135A/U, universal mounting bracket A-105, two copies of this instruction book, and the basic RF Wattmeter ME-11A/U. See figure 1-1 and table 1-1.

b. Power is measured under non-radiating conditions, i.e., with the transmitter disconnected from its antenna and feeding into the wattmeter only. This is an absorption wattmeter as distinguished from the other general class of "transmitted pow-

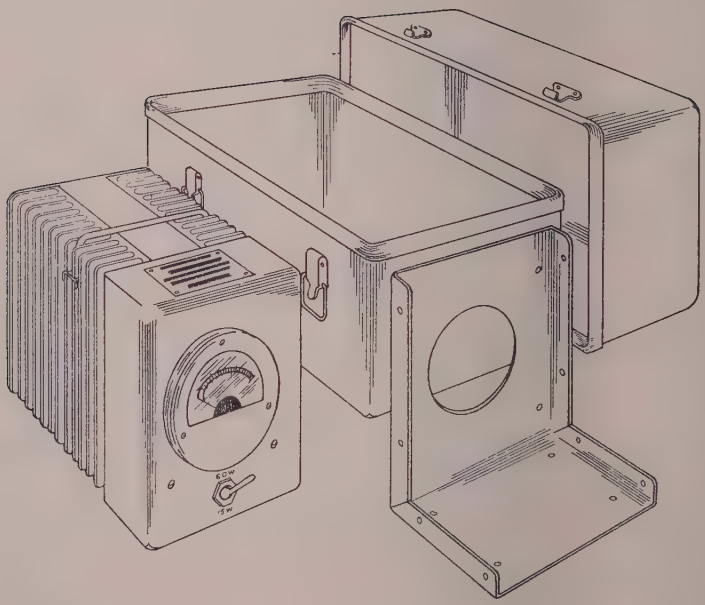

Figure 1-1. RF Wattmeter AN/URM-43A

er" or "thru" wattmeters.

c. The Wattmeter is built around an accurate coaxial resistor which is the transmitter load element. This resistor terminates 51.5 ohm lines so well that the voltage standing wave ratio remains below 1.1 up to above 600 mc/sec. The transmitter, when loaded by the Wattmeter, then operates into a known resistance of the value for which it was designed, and to a degree not often realized with antennas, particularly broad-band types.

d. Power input to the resistor is measured by means of a dual-range crystal voltmeter arrangement, the d-c meter of the voltmeter reading directly in rf watts.

e. This instrument is direct-reading in two ranges 0-15 and 0-60 watts, range selection being made by range switch on the front panel. No reference to calibration charts is needed. The meter scales are expanded at lower readings, i.e., half full-scale deflection is attained at about one third full-scale power.

4. SPECIFIC USES

The RF Wattmeter ME-11A/U may be used for the following purposes, among others:

a. Checking installation of transmitter.
b. Routine and trouble shooting maintenance.
c. Production and acceptance tests.
d. Transmitting tests.
e. Loss measurements on transmission lines.
f. Testing of coaxial line insertion devices, such as connectors, switches, relays, filters, tuning stubs, patch cords, etc.
g. As an accurate rf resistance, substantially independent of frequency and line lengths. See Section 4.
h. Modulation Monitor. Audio frequency amplitude modulation may be monitored by connecting phones, amplifiers, or audio voltmeters to the d-c meter circuit.

5. MAJOR COMPONENTS

(See figure 1-2.)

a. Figure 1-2 shows all components of the RF Wattmeter ME-11A/U, with the meter box detached to illustrate the arrangement for remote use of the indicating meter where the meter can-

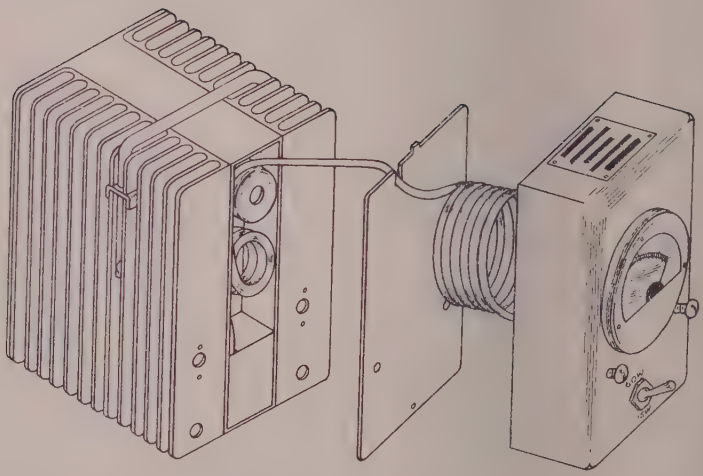

Figure 1-2. RF Wattmeter ME-11A/U, Meter Box Detached

not be conveniently read when attached to the Dummy Load-Voltmeter unit.

b. One shielded d-c cable is furnished, permanently connected between the dummy load-voltmeter and the meter box. The cable is 25 feet long to permit remote use of the meter box, with storage space in the meter box for normal use.

c. The sealed meter, M-101, is mounted in the meter box A-106. Mounted in the meter box also are the calibrating potentiometers, R-102, R-103, R-104, and R-105, the range selecting switch S-101, Resistor R-106, and spare crystal CR-102.

TABLE 1-1. EQUIPMENT SUPPLIED AN/URM-43A

Quantity per Equipment	Name of Unit	Nomenclature	OVER-ALL DIMENSIONS			Volume	Weight
			High	Wide	Deep		
1	RF Wattmeter	ME-11A/U	6.5	4.5	8.7	.15	6.4
1	Case, Meter (A-107)	CY-1135 A/U	7.2	5.7	9.2	.25	2.15
1	Bracket (A-105)		3.5	4.6	5.5	.04	.6
2	Instruction Books	NAVSHIPS 91842	7.5	5.5	.25	.006	.25

TABLE 1-2. SHIPPING DATA

Shipping Box No.	CONTENTS		OVER-ALL DIMENSIONS			Volume	Weight
	Name	Designation	Height	Widvn	Length		
1	RF Wattmeter	AN/URM-43A	10.	10.5	7.5	.45	12.5

Unless otherwise stated, dimensions are inches, volume cubic feet, weight pounds.

d. The Dummy Load-Voltmeter unit includes the coaxial load resistor, R-101, on which is mounted the voltage divider crystal

tap. The dummy load-voltmeter housing is oil filled and surrounded by a finned radiator structure. Mounted on the front of the housing is a neoprene expansion diaphragm which prevents pressure rise with temperature.

e. The crystal diode CR-101 is a Type 1N82, mounted in a holder located at the front of the load resistor housing.

SECTION 2
THEORY OF OPERATION

1. INTRODUCTION

There is very little lumped-constant, conventional circuitry in this instrument. Circuit elements are of the distributed constant type, machined and fabricated, as in microwave components.

2. BASIC PRINCIPLES

a. The power dissipated in a resistor is given by the relation $W=E^2/R$, where E is voltage across resistance R (figure 2-1). One of the oldest methods of measuring transmitter power at low radio frequencies depends upon this relation.

b. A small portion of a voltage developed across a resistor may be tapped off and applied to a voltmeter circuit. The tapped voltage is directly proportional to the applied voltage and the applied voltage is proportional to the square root of the power dissipated in the resistor. Therefore, the tapped voltage would also be proportional to the square root of the dissipated power.

c. In the RF Wattmeter ME-11A/U, resistor and connector are so designed as to have a constant characteristic impedance over a wide frequency range.

d. Since the coaxial lines and fittings for this frequency range generally are of 51.5 ohms nominal impedance, the wattmeter has been designed for this load resistance value. This accurately terminates such lines and fittings in their characteristic impedance.

e. SCALE SHAPES.

(1) The voltmeter E of figure 2-1, may be equipped with a direct reading scale in watts, for use with a definite load resistance R. This scale would be linear in watts if the voltmeter were of the square law type similar to thermocouple or iron vane meters.

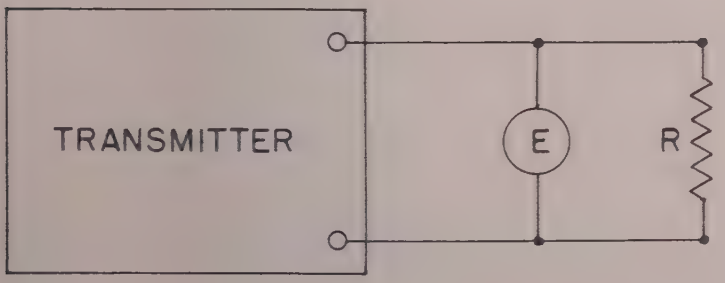

Figure 2-1. E^2/R Method of Power Measurement

Figure 2-2. Comparison – Illustrative Watt and Volt scales.

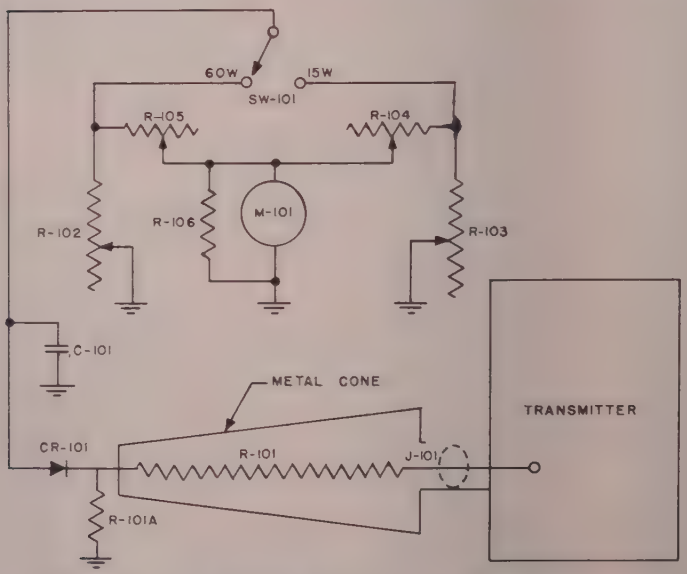

Figure 2-3. RF Wattmeter ME-11A/U Simplified Schematic.

(2) When the voltmeter is a linear type, the watt scale will be shown in figure 2-2.

3. LOAD RESISTOR CIRCUIT

(See Figure 2-4)

a. INPUT SECTION.—The structure is coaxial, having a characteristic impedance of 51.5 ohms from the RF input Jack, J-101.

b. RESISTOR PROPER.—The load resistance proper begins at the RF input Jack, J-101. The active power dissipating element is a carbon resistor which forms the inner conductor of the coaxial resistor. At the far end of the resistor the inner conductor is connected to a conical metal shell which forms the return conductor. The constant resistance properties of the assembly are dependent upon the shape of this shell and the distribution of resistance along the length of the carbon conductor. These factors have been worked out to give the desired results.

c. RF LOAD IMPEDANCE.—Voltage standing Wave Ratio Curves.

(1) Figure 2-5 shows the VSWR introduced by the Wattmeter when connected to a 51.5 ohm coaxial line. This smooth curve is free from rapid cyclical changes of VSWR, with frequency, which occur with lossy-line loads.

(2) The average curve represents results of tests on many instruments. All wattmeters will have VSWR's which fall below the "Allowable limit" curve.

(3) Below 150 mc. the VSWR curve is flat. The input impedance at J-101 is practically a pure resistance equal to the d-c input resistance.

(4) From 600 mc. to 900 mc. the VSWR may reach 1.2 at certain frequencies. The wattmeter may be used in this frequency range at full power rating, although the direct reading wattmeter calibration may be off.

4. RESISTOR HOUSING DESCRIPTION

a. The layout diagram Figure 2-4 indicates how the parts are arranged in the resistor housing. The circuit elements are de-

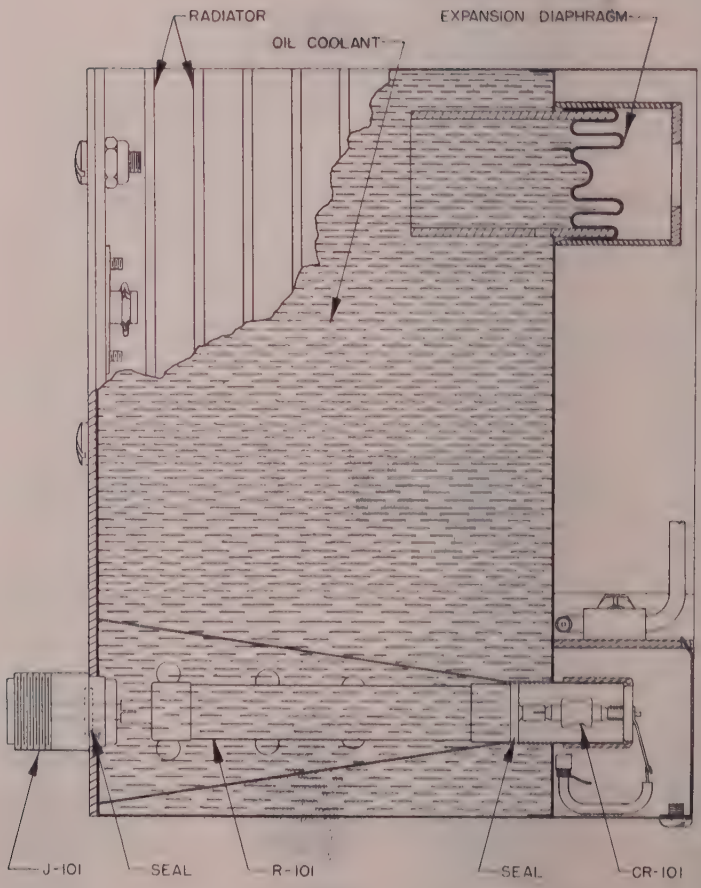

Figure 2-4. Layout Diagram, RF Wattmeter ME-11A/U.

signed into the structure to obtain the necessary rigidity.

b. DETAILED DESCRIPTION.

(1) Resistors R-102 and R-103 serve as part of the crystal diode load, enabling operation of the crystal at the proper portion of the diode characteristic curve.

(2) By-pass capacitor C-101 is a feed-thru button mica type. This capacitor is built into the crystal holder cover with center terminal acting as one crystal contact. This arrangement offers the most effective by-pass action with a minimum of residual inductance. As a result of careful design as well as of shielded d-c cables and a shielded meter, the wattmeter is insensitive to external r-f fields which might otherwise get to the crystal along the d-c lead.

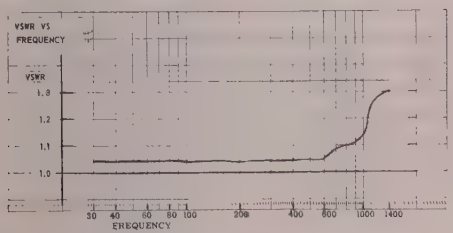

Figure 2-5. Voltage standing wave ratio vs Frequency RF Wattmeter ME-11A/U

5. CRYSTAL VOLTAGE LEVEL

The crystal operates at approximately 2.8 volts rectified d-c for full scale deflection on the 60 watt range, and at approximately 1.4 volts rectified d-c for full scale deflection on the 15 watt range. These values are conservative with respect to overload damage. It has been determined that four times full scale power can be applied momentarily without appreciable change in crystal characteristics or calibration.

6. CRYSTAL STABILITY AND RELIABILITY

a. ADVANTAGES.—The silicon crystal rectifiers used are

comparable to and in many respects superior to electron tube diodes. Some of their advantages are: smaller size, no filament supply, and no zero shift with time or change in line voltage.

b. From field experience with many similar instruments in industrial use, it has been found that calibrations will hold as well as in electron tube voltmeters. There is no indication of long time aging and calibrations may be expected to hold within 2% for variations chargeable to the crystals.

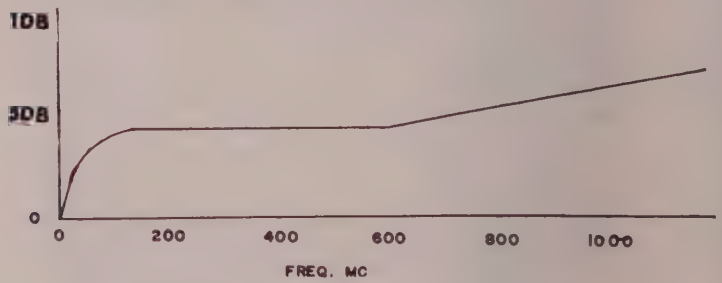

Figure 2-6. Power Calibration vs. Frequency RF Wattmeter ME-11A/U

7. POWER CALIBRATION VS FREQUENCY

(See figure 2-6.)

a. The frequency error of the average wattmeter is small except at the upper frequencies (750 mc. and above). The limit curves of figure 2-6 indicate the maximum deviations allowed in calibration.

b. Frequency errors between 30 and 600 mc. are within the required direct reading accuracy and ordinarily there is no need to use frequency correction.

c. The Wattmeter may read as much as 20% high between 600 and 1000 mc.

8. OVERALL ACCURACY CONSIDERATION

a. In the event that the termination does not match the transmission line properly, two errors occur: first, the voltmeter does

not take into account the power reflected from the load. This error which is small will be one percent or less for VSWR of 1.23 or less. The second error is considerably greater and can be as high as 10 percent with a VSWR of 1.1. This latter error is determined by the location of the voltage maxima and minima on the transmission line. If the load with the voltmeter was located at a point half way between a voltage maximum and minimum, the error would be due to the neglect of the reflected power. If the load is essentially resistive, the maximum or minimum voltage will occur at the point where the load and voltmeter are connected. This, which is likely to be the usual case, will cause the greatest error. If the termination is purely resistive, it may be any value between 56.7 ohms and 46.8 ohms and still satisfy the VSWR requirement of 1.1 or less.

b. If the VSWR is caused by a reactance so that the VSWR maximum or minimum does not occur at the load, the error will be less. However, the reactive part will be small in a good termination and these maximum errors are likely to be approached. If the resistor is the wrong value but maintains this value with negligible reactance over the frequency range, the voltmeter can be adjusted to compensate this error since it remains a constant. This is accomplished automatically by calibrating as described in Section 5 paragraph 4 or 5.

c. The errors caused by an improper termination have been the only error considered. Other errors will be contributed by the calibration, the meter movement and the crystal rectifier. The errors due to the calibration and meter movement probably will be relatively fixed with time. The errors caused by the crystal rectifier, however, could be a function of temperature as well as different crystals. Also the voltage divider may be frequency sensitive and can contribute a small error. All these errors must be added to that of the termination. Thus, if a wattmeter of this type is to have a high degree of accuracy for cw power, all factors must be controlled to a very high degree of accuracy. It is impractical to expect this type wattmeter to have the same order of accuracy as that of calorimeter and bolometer type wattmeter.

d. There will be some variation in the resistance value of

the load resistor, with temperature change, but this is very slight, less than .04 ohms per degree centigrade, and introduces a VSWR change of less than .06% per degree centigrade.

e. The causes of errors have been considered and the question of how much overall error should be tolerated in this type of meter arises. Probably this can be determined best from the manner the meter will be used in evaluating a system in the field. Most systems must have a tolerance to handle ordinary performance variations. In evaluating a practical system an accuracy tolerance of about one decibel should be allowable. Thus, a variation of 0.8 db should be satisfactory. It should be noted that the accuracy of the usual signal generator voltmeter will be no better than about 0.8 db.

9. COOLING SYSTEM

a. HEAT TRANSMISSION

(1) To assure full powe rating, the cylindrical carbon resistor, R-101, is immersed in oil which carries heat by convection to the inside wall of the load resistor housing through openings in the conical metal shell. From there heat is conducted through the fins and carried away by air convection. The cooling system of the wattmeter is conservatively rated. It will handle rated power (60 watts) continuously without damage at an ambient temperature of 40° Centigrade (104° Fahrenheit).

(2) The coolant used is a high flash point transformer oil, conforming to Federal Specification VV-0-401.

b. ELECTRICAL SIGNIFICANCE OF COOLANT.—The unit must be reasonably full of proper coolant in order to dissipate its rated power. A loss of more than 25% of the coolant volume may impair this. Careful attention has been given to obtaining a design which is leak proof under service conditions. Slight leakage at any point on the resistor housing will be of little consequence, becoming serious only through cumulative loss of coolant.

The dielectric constant of the coolant is an important factor in determining the input impedance. The dummy load-voltmeter is designed so that a loss of as much as 66% of the coolant vol-

ume will not affect the input impedance, providing the unit is in an upright position.

10. TEMPERATURE EFFECTS

a. Particular attention has been given to design so that ambient temperature has negligible effect on power calibration and input impedance within the specified temperature range of −40° Centigrade (−40° Fahrenheit) to +55° Centigrade (151° Fahrenheit).

b. The voltage standing wave ratio changes less than .02 between "no" load and "full" load (60 watts), and power calibration varies less than 2% within normal operating limits.

11. INPUT RESISTANCE D-C, SIGNIFICANCE OF

a. The d-c resistance at the input jack J-101 is not critical, and, with various dummy load-voltmeter units, will range between 49 and 53 ohms. The d-c resistance measured at the factory will be found stamped inside the crystal housing cover. Any significant deviation from this value requires recalibration of the wattmeter. (See Section 5, paragraph 4 for calibration procedure).

b. This d-c resistance measurement should be made with an accuracy of plus or minus 1% on a bridge such as Resistance Bridge ZM-4/U.

A measured value differing by more than two ohms from the value marked on the crystal housing is significant of a calibration change. A resistor which has been subjected to considerable overload normally measures higher in resistance.

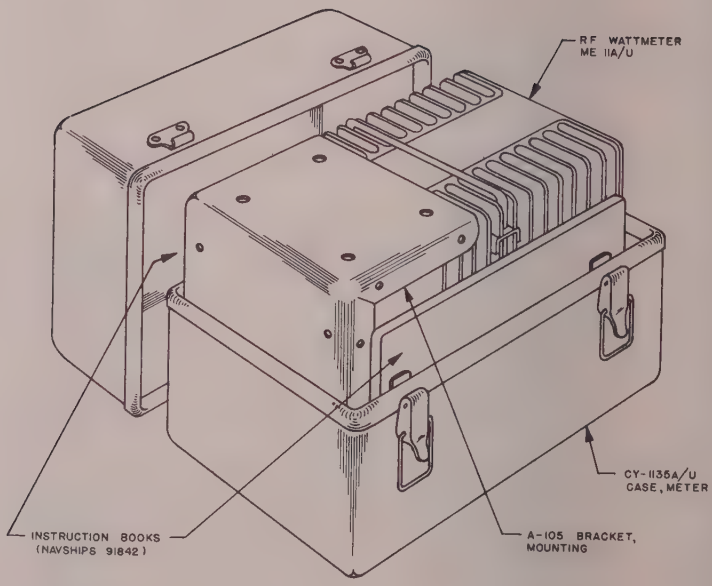

Figure 3-1. Method of Packing Transit Case

SECTION 3
INSTALLATION

1. PORTABILITY

The RF Wattmeter AN/URM-43A is a portable test equipment. The transit case CY-1135A/U furnished with the wattmeter, is supplied containing all of the equipment designated in Table 1-1, and serves to carry all of the included material as a unit package. The method of repacking the equipment for correct closure is simple, and is illustrated in figure 3-1.

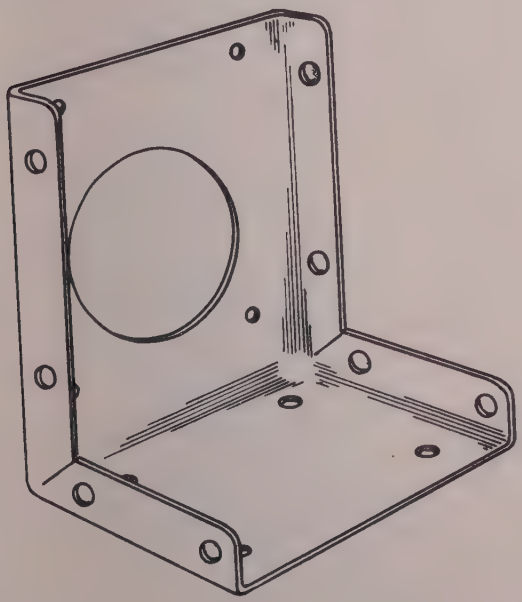

Figure 3-2. Outline Universal Mounting Bracket

2. OPTIONAL FIXED MOUNTING

a. The RF Wattmeter should be placed as close as possible to the point at which the power output reading is desired. The Wattmeter may be used and installed as a standing unit or may be fixed mounted by use of the universal mounting bracket A-105 provided. Drawing of this bracket appears in figure 3-2. For fastening the wattmeter to the bracket, the four rubber feet should be unscrewed from the bottom of the radiator. The thread bolts thus exposed may be used with four 8-32 nuts (or the original rubber bumper feet) to mount the wattmeter. These bolts will readily line up with the four slotted holes on the Universal Mounting Bracket A-105.

b. The bracket A-105 may be fastened to a panel, partition or any vertical member by means of four 1/4-20 machine bolts with

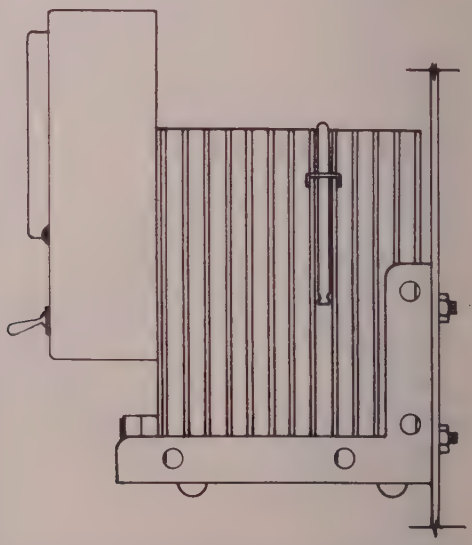

Figure 3-3. Bracket Mounting of RF Wattmeter

nuts and appropriate washers (not furnished with this equipment). The bracket may be fastened on side, either right hand or left hand, or may be end mounted, as illustrated in figure 3-3. For any of these methods the respective face of the bracket will readily serve as the hole layout template.

c. When the unit is bracket mounted as described above, the meter box A-106 may still be detached where desirable for reading in remote location.

3. LOCATION

a. Free circulation of air around the wattmeter is necessary if operated above 30 watts for more than a few minutes. Keep it well ventilated and avoid mounting it on, or alongside of, heated surfaces.

b. Where possible, operate in the normal position, feet resting on a horizontal surface, with at least 4" clearance on all sides. Space above wattmeter should be kept as clear as possible for good heat convection. Air cooling is most effective in this position and is important above 30 watts.

c. Avoid operation in the "J-101 UP" position, i.e., resting on the end normally holding the meter housing. In this position, any air within the coolant space will collect around the input jack (figure 2-4) and a change of dielectric constant in this region will affect calibration.

d. The meter box may be mounted at the rear of the dummy load-voltmeter unit by detaching it from the front, as explained in paragraph 4 of this Section, and attaching to the rear by means of two screws.

4. REMOTE USE OF METER BOX

a. The meter box A-106 is quickly detached by removing the two 8-36 machine screws on the front of the meter box (figure 1-2) and may be located remote from the dummy load-voltmeter unit if required.

b. For remote operation the d-c cable, normally coiled inside the meter box, may be pulled out to its full length (25 ft.).

SECTION 4
OPERATION

1. TO MEASURE TRANSMITTER POWER

a. The wattmeter may be connected directly to the transmitter without removing the meter box, by means of a Type N double male adapter, such as the UG-57( )/U series or higher. If this is not practical, locate the wattmeter where a short coaxial cable, preferably not over five feet long, will connect the transmitter to the wattmeter and where conveniently readable while adjusting the transmitter.

b. By means of the SCALE SELECTOR SWITCH S-101, select the desired power range (15 watt or 60 watt scale). If in doubt set switch S-101 to 60 watt scale.

c. With the TRANSMITTER OFF, disconnect the antenna line and connect the wattmeter as shown in figure 4-1.

d. Use a patch cord, consisting of a 50 ohm cable such as RG-8 U or RG-9/U and 50 ohm Type "N" plug, such as the UG-941 Series, or the UG-21B/U plug or higher.

e. Turn the TRANSMITTER ON. The wattmeter will indicate the power being delivered. Read the wattmeter, using the 15 watt range if indication is below that value.

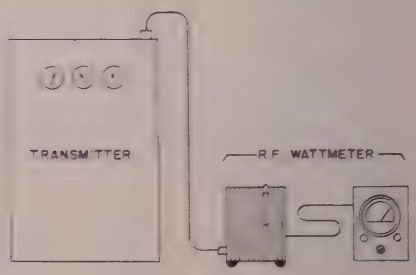

Figure 4-1 Typical Connections to Transmitter

f. If adjustment of the transmitter is necessary, follow the pertinent instruction book. OBSERVE SAFETY PRECAUTIONS about high voltages in the transmitter. The wattmeter indicates results of tuning, directly in watts for the standard termination of 51.5 ohms offered by the wattmeter.

g. When the desired output power has been obtained, NOTE THE READINGS of the wattmeter, and of the meters provided on the transmitter, particularly of the plate current and voltage meters on the final stage and of antenna line monitor. These readings bear a direct relationship to power output, and are useful in relating transmitter output into its antenna, to output into the wattmeter.

h. TURN TRANSMITTER OFF before opening RF connections to the wattmeter.

i. RECONNECT THE ANTENNA LINE-TURN TRANSMITTER ON and note its meter readings. If the antenna impedance (VSWR) is correct, the transmitter meters will read as they did with wattmeter connected. Some allowances should be made for the fact the VSWR's around 2 to 1 are normal at some frequencies in the range of good broad-band antennas.

j. In case of a significant difference between transmitter meter readings on wattmeter and antenna, RETUNE THE FINAL TANK AND ANTENNA COUPLING, using plate dip methods of antenna monitor readings as specified in instruction book for transmitter.

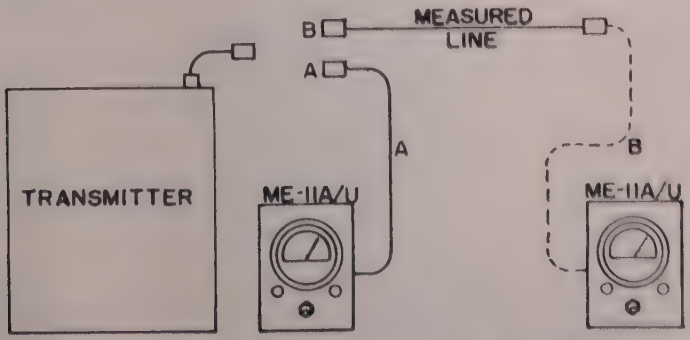

Figure 4-2 Line Loss Measurement – Block Diagram

k. REPEAT THE ENTIRE PROCESS FOR EACH NECESSARY FREQUENCY.

2. TO MEASURE LINE LOSS

a. GENERAL.—Loss measurements on 50 to 52 ohm coaxial cables may be made with the wattmeter. A transmitter whose rated output is 15 watts or more is required as a test power source. For maximum reading accuracies, use powers between 10-15 watts on the 15 watt scale, or 50-60 watts on the 60 watt scale.

b. TEST PROCEDURE *(See figure 4-2 and 4-3.)*

WARNING

Always turn power off when connecting or disconnecting wattmeter or antenna.

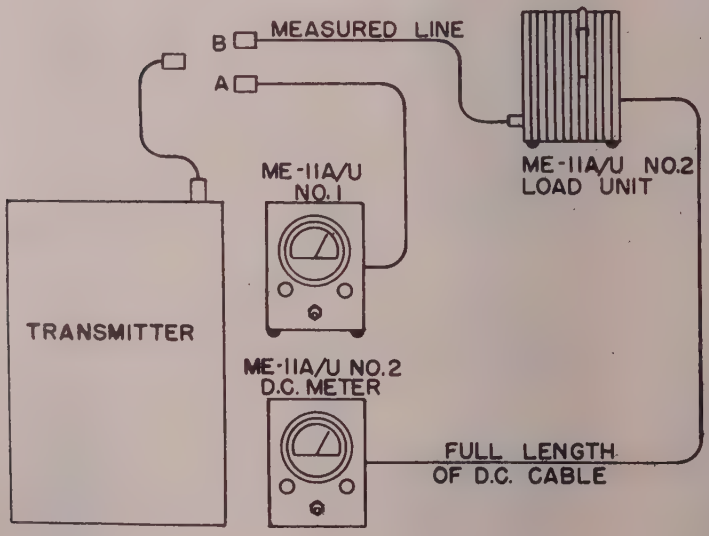

Figure 4-3. Line Loss Measurement – Remote use of D-C Meter Block Diagram

(1) Connect the wattmeter to the transmitter ("A" connection of figure 4-2 and 4-3). Read output power and tune final stages of transmitter for desired power output "P_1".

(2) Connect line to be measured to transmitter and connect wattmeter to far end of line ("B" connection of figure 4-2 and 4-3). Read Power "P" if the transmitter meters do not indicate a significant change in loading. Good lines terminated by the wattmeter should show little change in transmitter loading from that with wattmeter alone. Where significant changes occur, the voltage standing wave ratio of the line is high and attenuation measurements by this method should be disregarded. Cause of high VSWR should be investigated.

(3) The loss may be expressed either as a power ratio P_1/P_2, or in decibels using the formula:

$$\text{Loss} = 10 \log_{10} \frac{P_1}{P_2} \quad \text{decibels}$$

(4) Example: Assume P_1 is equal to 60 watts with wattmeter connected to transmitter. Assume P_2 for the "B" connection 23 watts, with the transmitter operating conditions unchanged. Substituting these figures in the above formula:

$$\text{Loss} = 10 \log_{10} \frac{60}{23} = 10 \times .416 = 4.16 \text{ db.}$$

c. ACCURACY.

(1) The procedure and accuracy of this method is suitable for installation, operating and maintenance activities. It is a practical measurement in that the combined effects of true attenuation (Power lost in heating the line), and of reflections caused by the line are given by one measurement.

(2) With reasonable care in holding the transmitter power constant, this method is accurate to within 0.5 db., under the best conditions, results within 0.2 db. are obtainable, providing the VSWR of the measured line is low.

d. ALTERNATE CONNECTIONS

(1) When both ends of the measured line terminate in the transmitter room, one wattmeter's measurements are convenient. (See figure 4-2.)

(2) A dual set-up with wattmeter and personnel at each end

of the line may be used where the far end of the line to be measured is remote, especially when a number of frequencies or parallel lines are to be checked. With readings to be taken at both ends a telephone connection serving as an order wire will save time.

(3) Figure 4-3 shows one way of carrying out line measurements from the transmitter room only, when far end of line is remote.

(4) When two or more rf lines run parallel between measurement points, join two lines with a patch cord at the remote end, then measure the loop back to the transmitter room. For identical lines, the loss of one is half the loop loss, or the loss of one good line can be otherwise determined and subtracted from the loop loss.

3. TO CHECK COAXIAL INSERTION DEVICES

a. The term insertion devices is used to mean all forms of connectors, patch cords, switches, relays, filters, tuning stubs, etc. These devices are normally low loss units and true power loss is frequently below that measurable with accuracy. Insertion devices specifically designed for high attenuation may be checked for their loss as outlined in paragraph 2 above.

b. Tests made in accordance with paragraph 2 above will not show a readable power loss for a low loss insertion device in good condition. These tests may be considered "IN-OUT" test in which the optimum performance is indicated by no readable change in wattmeter reading, whether the insertion device is in or out.

c. Tests may be either routine, simply to see that the device works, or they may attempt to discover more closely just what the insertion effect is. In the latter case, time stability of the transmitter is all important since the results depend on the difference between two readings not taken simultaneously.

4. MODULATION MONITOR

On amplitude modulation, the d-c meter action of the wattmeter is typical of diode rectifiers i.e., meter reading generally is constant regardless of normal modulation.

a. AUDIO AVAILABLE.—When connected to an amplitude modulated transmitter, audio signals are present across the d-c cable terminals through the demodulating action of the voltmeter diode. This signal may be used conveniently for monitoring modulation aurally, and for certain measurements on audio characteristic of the transmitter. Specific connectors are not provided for this use.

b. CONNECTIONS

(1) High impedance phones may be bridged across the d-c cable most conveniently at the crystal contact chuck or in the meter box. Precaution should be taken to prevent mechanical strains on the soldered connections.

(2) If an audio coupling capacitor, of .01 to 0.1 mfd. value, is used in series with the phones, the power calibration will be unaffected by the d-c shunting action of the phones.

CAUTION

In all such use of the wattmeter, use care to avoid stray voltage being impressed across the d-c cable from the wattmeter. Remove crystal before changing connections to the external d-c circuit. A small shielding box for the phone jack is advisable. Because of body static particularly, and rf secondarily, don't touch the d-c lead while connected to the crystal.

5. AUDIO RESPONSE MEASUREMENTS

With suitable auxiliary equipment including an audio oscillator, audio voltmeter and amplifier, the audio response curve of a transmitter may be run. Best results are obtained by connecting a resistance, 500 to 1000 ohms, in place of the d-c meter, and the amplifier input across this resistance. Without an amplifier, an audio voltmeter with approximately 1 volt full scale will give usable deflections when connected across the d-c cable, without any shunt resistance or d-c meter.

6. DISTORTION

The crystal diode CR-101 is not linear enough as a voltage rectifier to make accurate checks on distortion percentages.

However, serious form of distortion in the transmitter can be detected aurally.

7. USE AS A DUMMY LOAD ONLY

RF Wattmeter ME-11A/U can be used as an accurate termination of 51.5 ohms at all frequencies from zero (d-c) to above 900 mc.

8. USE AS A LOW FREQUENCY WATTMETER

Power may be measured below the calibrated range of the rf wattmeter, ME-11A/U by adding sufficient filter capacity across the crystal output. For radio frequency signals below 30 mc a mica capacitor of at least .1 mfd should be connected in parallel with C-101. For audio frequency power measurements, a 1000 mfd electrolytic capacitor may be connected in parallel with C-101 with the positive terminal on the ground side.

CAUTION

Do not exceed the rated capacity of the wattmeter.

9. GENERAL OPERATING NOTES

a. OPERATING NOTES.

(1) Be careful about the condition of rf cables and connectors used in the rf circuits to the wattmeter. Proper assembly of connectors to cables is important for electrical reasons.

(2) Avoid faulty assembly of the latest type "N" plug connecting to J-101 on the wattmeter. The center contact sleeve of J-101 is not replaceable if damaged.

(3) Patch cord lengths, adaptors and connectors should be kept to a minimum. The latest type "N" or other constant impedance 50 ohm, connectors and adaptors should be used.

(4) Where non-constant impedance connectors must be used, as with transmitters having the output jack, Navy type 49194 (Type SO-239), keep them at the transmitter jack only, so that patch cord will be free from standing waves. In other words, the VSWR will be low on good 50 ohm cables and fittings, from the wattmeter back to the first significant discontinuity, and this should include as much of the total circuit length as possible.

(5) Adaptors, of any type, should be used at the transmitter end rather than the wattmeter end.

(6) The coaxial cable (Patch Cord) connecting the transmitter to the wattmeter should be made up of a 50 ohm cable with UG-21B/U series (or higher) plug at one end for the wattmeter connection and a plug, such as UG-941/U series, mating with the transmitter jack for the other connection. This procedure eliminates the need for additional adaptors. For example, if the transmitter utilizes a Navy Type 49194 Jack, the connecting cable should be made up of a UG-21B/U plug, RG-8/U or RG-9/U cable, and a Navy Type 49195 plug.

(7) Use only 50-52 ohm cables and fittings if possible. Thus, even in the use of a transmitter having nominal 75 ohm output, 50 ohm lines should be used up to the necessary point of change to something else, at the output jack of the transmitter. Equal impedance of wattmeter and cable is more important than equality between transmitter and cable.

b. OPERATORS TESTS FOR ACCURACY.

(1) Operating checks should consist of comparison between wattmeters of this type.

(2) An approximate check of crystal diode CR-101 may be made by obtaining a reading from a power source, and then replacing the crystal with another crystal that is known to be good. If the readings are close (within 5 watts on the 15 watt scale, 20 watts on the 60 watt scale) the original crystal is good.

NOTE

If the crystal must be replaced, the wattmeter must be recalibrated in order to maintain the specified accuracy. This procedure is described in Section 5, Maintenance, paragraph 4.

(3) The two power ranges may be cross checked most accurately at 10 to 15 watts input power. The 60 watt range should read within 2 watts of the reading on the 15 watt range.

(4) Comparison of two wattmeters is a practical check on both units. If precautions are taken to maintain the stability of the transmitter, readings should then be equal within 10%, for readings above 1/5 of full scale. Assuming both wattmeters

remain unchanged from time of calibration, the largest sources of error in this comparison are:

(*a*) The real error due to the possible differences in frequency response curves (figure 2-6).

(*b*) The apparant error due to normal differences between the exact input impedance values of the two wattmeters.

Minimizing (*b*) above depends upon whether the transmitter shows a direct relationship between final plate current and power output and whether it has an antenna coupling adjustment. Wattmeter comparisons can be more accurately made by adjusting tuning and coupling, on the final tank to the same plate current and voltage values for each wattmeter.

c. WATTMETER VS ANTENNA AS LOADS.

(1) The wattmeter may load the transmitter differently from the antenna. This may be normal for broad band antennas due to voltage standing wave ratio variation at different frequencies. Since the purpose of the transmitter is to drive the antenna, a slight retuning of the final tank and antenna coupling may be advisable as described below.

(2) An antenna line monitor (provided in certain transmitters) indicates relative voltage or current at one point in the antenna circuit. The final adjustments should aim at peaking this meter. It will correctly indicate relative power output as long as the load impedance remains fixed. A change of antennas or frequency may cause large variations in load impedance and therefore the monitor readings are unreliable for indicating absolute power.

(3) The line monitor may show a large change of reading, roughly, as much as 1.5 to 1 for a VSWR of 2.0 when the antenna is substituted for the wattmeter.

(4) The power values into the antenna and the wattmeter will be essentially equal if the VSWR on the antenna line is small. This condition may be recognized if after peaking, employing either the line monitor or plate current dip as an indicator, the final amplifier plate current and plate voltage are the same.

d. POWER MEASUREMENTS VS. FREQUENCY.

No correction factors are necessary for use in the specified frequency range (30-600 mc., see figure 2-6). Measurements will be within the required limits over this range.

SECTION 5
MAINTENANCE

1. INTRODUCTION

The circuit simplicity and mechanical design of the wattmeter results in a minimum of maintenance since all electrical circuits are sealed and rigidly mounted.

This unit, therefore, requires no field maintenance.

Preventive and corrective maintenance are grouped together in this section.

Figure 5-1. Wiring Diagram, RF Wattmeter ME-11A/U

2. GENERAL MAINTENANCE

(See figure 5-1 Wiring Diagram)

a. Keep Jacks and plugs clean. Keep the crystal diode CR-101 in its holder at all times and keep the holder closed tightly.

b. Dropping is the most likely source of damage, the D.C. meter M-101 being the critical item. DO NOT DROP IT.

c. When two wattmeters are used together, do not allow the meter boxes and dummy load voltmeter units to be interchanged, or a change in calibration will occur.

3. REPLACING CRYSTAL

Figure 5-2 shows the mounting of the crystal diode in its holder. Detaching the meter box from the dummy load voltmeter unit exposes the crystal housing cover. Remove the crystal housing cover. Pull the crystal contact chuck assembly off. The crystal diode may then be pulled from its chuck and a new crystal diode inserted.

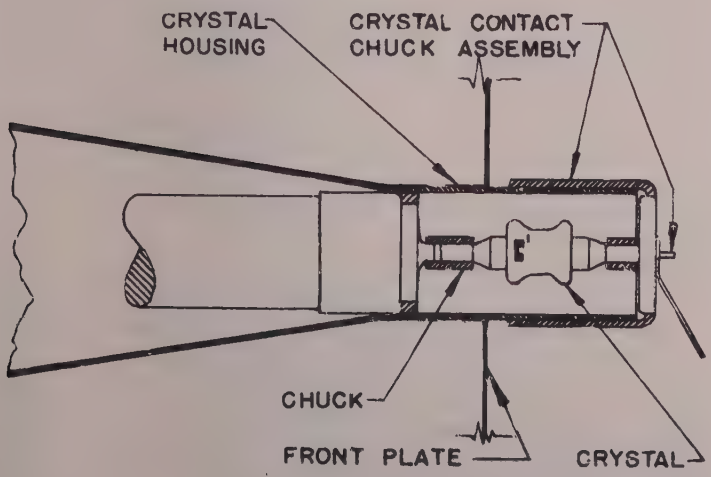

Figure 5-2. Assembly of Crystal Housing

Note

THE CRYSTAL MUST BE INSERTED WITH THE WHITE BAR (CATHODE) TOWARD THE LOAD RESISTOR.

This is necessary to obtain proper polarity of the rectified dc voltage.

The crystal contact chuck assembly is then carefully slid into the crystal housing. Be sure that the crystal leads are inserted into their chucks. The crystal housing cover is then replaced.

4. CALIBRATION

a. If a new crystal must be installed the wattmeter must be recalibrated in order to maintain the accuracy of the instrument thus, the necessity of using matched crystals in eliminated and most IN82 crystals may be used.

b. The most convenient method of calibrating the instrument is to apply a known amount of power to the load resistor and adjust the calibrating potentiometers to give the proper reading on the meter. A 60 cycle power source may be used, but the difference in output circuit impedance at this frequency must be considered and adequate filtering must be provided. The following procedure takes these factors into consideration and provides accuracies to within .8 db. If greater accuracy is desired a "through" type rf power meter must be used.

c. For calibrating with ac, a variable source of ac power, such as a variac, and an ac power meter with 1/2 of 1% accuracy will be required. A short length of coaxial cable with alligator clips on one end should be used to connect the rf wattmeter to the ac wattmeter.

d. CALIBRATION PROCEDURE.

(1) When the crystal has to be replaced or it is suspected that the crystal in use has been damaged, the instrument should be recalibrated using the procedure described below. For this calibration, it is necessary to use an accurate AC wattmeter having a full scale deflection of approximately 0-60 watts, and an electrolytic capacitor of a 1000 mfd or more, with a voltage rating of at least 50 volts, connected across the rf cable terminal lugs in the meter box, with positive terminal on the shield of the cable.

(2) 15 WATT SCALE ADJUSTMENT:

(*a*) Since there is some interaction between the controls for the 15 watt scale and the 60 watt scale, the 15 watt scale has to be calibrated first.

(*b*) With the rf wattmeter set to 15 watt position and connected as shown in figure 5-3, set the variac for minimum output, and apply power to the circuit. Adjust the variac for 15 watt reading on the ac wattmeter and adjust R-104 for 15 watt reading on the ME 11A/U. Decrease variac output to 4 watts and adjust R-103 so that the ME 11A/U reads 4 watts. Repeat 15 and 4 watt adjustments until proper.

NOTE

If ME 11A/U meter reads slightly low at 4 watt position disconnect ground contact of R-103. If this does not correct the reading discard the 1N82 crystal and secure one that will meet the calibration requirements.

(3) 60 WATT SCALE ADJUSTMENT.

(*a*) With the rf wattmeter set to 60 watt position and connected as shown in figure 5-3, set the variac for minimum output, and apply power to the circuit. Adjust the variac for 60 watt reading on the ac wattmeter and adjust R-105 for 60 watt reading on the ME 11A/U. Decrease variac output to 15 watts and adjust R-102 so that the ME 11A/U reads 15 watts. Repeat 60 and 15 watt adjustments until proper.

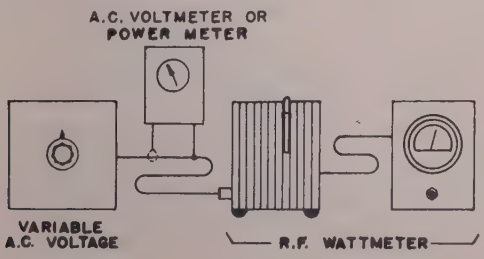

Figure 5-3. Calibration of RF Wattmeter by means of A.C.

NOTE

If ME 11A/U meter reads slightly low at 15 watt position disconnect ground contact of R-102. If this does not correct the reading discard the 1N82 crystal and secure one that will meet the calibration requirements.

(*b*) Recheck and if necessary, readjust 15 watt scale adjustments as described above.

(4) Remove crystal contact chuck and measure resistance across cable. For maximum accuracy, select crystals to give a resistance over 500 ohms with S-101 in either position.

5. ALTERNATE CALIBRATION PROCEDURE.

a. If an ac wattmeter is not available the rf wattmeter ME-11A/U may be calibrated as follows:

b. The power applied to the load resistor may be accurately computed, using the values shown in figure 5-4. This graph takes into account the change in resistance due to temperature rise when power is applied to the load resistor, and will give a calibration accuracy of .8 db or better.

c. When using this method of calibration a variable source of ac voltage, such as a variac, and an ac voltmeter with 1/2 of 1% accuracy are required. A short length of coaxial cable with alligator clips on one end should be used to connect the rf wattmeter to the ac voltmeter.

(1) Measure the dc resistance of the load resistor, using a resistance bridge with an accuracy of 1/2 of 1%. If such a bridge is not available use resistance value stamped inside crystal compartment.

(2) 15 WATT SCALE ADJUSTMENT.

(*a*) Since there is some interaction between the controls for the 15 watt and 60 watt scale, the 15 watt scale must be calibrated first.

(*b*) With the rf wattmeter set to 15 watt position and connected as shown in figure 5-3 set the variac for minimum output, and apply power to the circuit. Adjust the variac for the voltage indicated in figure 5-4 to give the 15 watts for the determined value of the load resistor and adjust R-104 for 15 watt reading on the ME-11A/U. Decrease variac output to the voltage indi-

cated in figure 5-4 for 4 watts and adjust R-103 so that ME-11A/U reads at the 4 watt position on the 15 watt scale. Repeat 15 and 4 watt adjustments until proper.

NOTE

If ME-11A/U meter reads low at 4 watts, disconnect one contact of R-103. If this does not correct the reading discard the 1N82 crystal and secure one that will meet the calibration requirements.

(3) 60 WATT SCALE ADJUSTMENT.

(*a*) With the rf wattmeter set to 60 watt position and connected as shown in figure 5-3, set the variac for minimum output and apply power to the circuit. Adjust the variac for the voltage

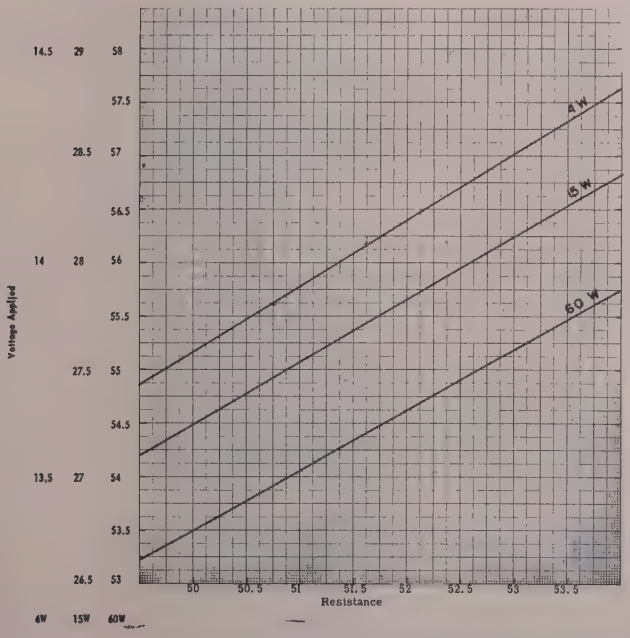

Figure 5-4. Calibration Voltage Graph

indicated in figure 5-4, to give 60 watts for the determined value of the load resistor and adjust R-105 for the 60 watt reading on the ME-11A/U. Decrease variac output to the voltage indicated in figure 5-4 for 15 watts and adjust R-102 so that ME-11A/U reads at the 15 watt position on the 60 watt scale. Repeat 60 and 15 watt adjustments until proper.

NOTE

If ME-11A/U Meter reads low at 15 watts, disconnect one contact of R-102. If this does not correct the reading discard the 1N82 crystal and secure one that will meet the calibration requirement.

(*b*) Recheck and if necessary readjust 15 watt scale as described above.

(4) Remove crystal contact chuck and measure resistance across cable. For maximum accuracy, select crystal to give a resistance over 500 ohms with S-101 in either position.

6. ELECTRICAL TESTS

a. The simplest overall test of the wattmeter is the comparison test discussed in Section 4, paragraph 9*b*.

b. D-C METER TESTS.—Testing of the meter should be attempted only by one familiar with circuits and instruments for testing of sensitive d-c microammeters because of the danger of damaging it in unsuitable circuits. Remove the crystal contact chuck, A-103, disconnecting the meter box from the dummy load voltmeter. Disconnect resistor R-106 by unsoldering one of its leads. Test the meter as a microammeter in series with a low voltage battery, variable resistor and an external microammeter such as in the multimeter TS-352/U series. Full scale current on meter M-101 should be 200 microamperes ± 2%.

CAUTION

M-101 is a sensitive microammeter. Do not attempt to check with ohmmeter.

c. D-C CABLE TESTS.—May be made with an ohmmeter and a megger. Disconnect cable from both voltmeter and meter for test. Check continuity and leakage.

d. SIMPLE TEST ON VOLTMETER CIRCUITS.—Remove

the crystal contact chuck, A-103, from the dummy load voltmeter housing before making any tests.

(1) The resistance to ground measured at the exposed crystal lead indicates the resistance of the crystal. The forward resistance of the crystal is measured with the "common" lead of the ohmmeter, at ground, the positive lead at the exposed crystal lead. The ohmmeter should read between 200 and 800 ohms. Reversing the ohmmeter leads will indicate the backward resistance of the crystal. The ohmmeter should indicate above 50,000 ohms.

(2) The portion of the load resistor that develops the voltage applied to the meter circuit is tested in the following manner: with the crystal removed, apply 60 watts of a-c to the dummy load voltmeter. Measure the a-c voltage developed at the crystal chuck inside the crystal housing. The voltage should be between 2.6 and 3.1 for proper crystal operation.

e. TESTING THE LOAD RESISTOR.—An accurate resistance measuring instrument such as Resistor Bridge ZM-4/U good to 1% or better at 50 ohms is required. Refer to Section 2, paragraph 3. Using low resistance leads (preferably a short piece of RG-8/U connected to the UG-21B/U plug) measure the load resistor R-101. A change of more than 2 ohms from the original value stamped on the back of the meter box cover is an indication that the r-f resistance has changed significantly and that the wattmeter should be recalibrated. The coolant level should also be checked when measuring the resistor.

7. CHECKING COOLANT LEVEL.

a. The general significance of oil seepage or leaks which may occur has been discussed in Section 2, paragraph 9. Avoid tampering with any of the various joints at which the oil is sealed.

b. To check the amount of coolant in the dummy load-voltmeter housing:

(1) Detach meter box (See Section 3, paragraph 4 for instructions.)

(2) Place dummy load-voltmeter on its back (diaphragm housing up.).

(3) Remove diaphragm cover H-105.
(4) Carefully remove diaphragm A-102.

c. Before replacing diaphragm, the coolant should be poured into a container and heated to approximately 150° F. (66°C.). The coolant should then be poured into the dummy load-voltmeter housing, while hot, and the diaphragm (A-102) and cover (H-105) replaced. A screwdriver handle approximately 3/4 inch in diameter is convenient for pushing the diaphragm into it's housing. Three-quarters of an inch to one inch of the diaphragm should protrude to provide for folding around the outside of the diaphragm housing. The cover is then gently pressed on.

The purpose of heating the coolant, before pouring into the dummy load-voltmeter housing, is to prevent too great a pressure from being developed in the housing, when the wattmeter is used at (or near) full power for prolonged periods of time.

d. If necessary to add or replace coolant, use only transformer oil, VV-0-401, Standard Navy Stock No. W14-0-3530.

8. REPAIR OF LEAKY DUMMY LOAD-VOLTMETER HOUSING.

If coolant seepage is noticed, the point of origin of the seepage should be located. If necessary, remove the cooling fins by removing the 8-36 machine screws holding the fins to the housing. Pour out the coolant as explained in paragraph 6 of this section. The spot where seepage occurred should be cleaned and then soldered with a 300 watt soldering iron. DO NOT use a torch.

SECTION 6
PARTS LIST

TABLE 6-1. LIST OF MAJOR UNITS

Symbol Groups	Quantity	Name of Major Unit	Navy Type Designation
101 to 199	1	RF Wattmeter F16-Q-123759-100	AN/URM-43A

TABLE 6-2.

TABLE OF REPLACEABLE PARTS

Ref. Designation	Navy Stock Numbers	Name and Description	Locating Functions
A-101	—*	DUMMY LOAD-VOLTMETER assy. Resistive dissipation type. 51.5 ohms; 60 W. dissipation. 21 gage galvanized iron, 5-7/16 in. lg., x 4-½ in. w. x 6.5 in. h. Inc. R-101, J-101 and cooling fins. EIL 109C1025.	Wattmeter Load
A-102	—*	DIAPHRAGM, Expansion, Duroneoprene, #40, .020 in. th.,	Maintain constant pressure with

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the item cannot be repaired or fabricated.

Ref. Designation	Navy Stock Numbers	Name and Description	Locating Functions
A-102 *(Cont.)*		3-1/8 in. lg., 15/16 in. dia. EIL109A1020.	variation in temperature.
A-103	–*	ASSEMBLY, Crystal contact chuck, brass, silver plated, 25/32 in. lg., 9/16 in. dia. with rf bypass capacitor C-101. EIL109A1012	Crystal cover and one side of crystal contact.
A-104	N33B-1225 500	BUMPER, Foot, Rubber, 5/8 in. dia. 5/16 in. lg. with brass 8-32 insert hemispherical. AIRW 868-2	Shock mounting foot
A-105	–*	BRACKET, Universal mounting, steel, gray enamel, 5.5 x 4-13/32 x 3.5, perforated for ventilation and mounting. EIL 109C1071.	Mounts meter
A-106	–*	HOUSING, meter, al alloy, #14. Box 2 x 6 x 4-11/32 with openings for scale and switch with rear cover. EIL 109C1067.	Cases front of unit and supports meter
A-107	–*	CASE, meter, al alloy gray enamel finish, 9-3/16 x 5-7/16 x 7. Lid has carrying handle on top. CY-1135 A/U EIL 109C1070.	Transit case for RF wattmeter ME-11A/U and Instruction Books.

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the item cannot be repaired or fabricated.

Ref. Designation	Navy Stock Numbers	Name and Description	Locating Functions
C-101	—*	CAPACITOR, disc. type, 150 mmf ± 10%. Part of A-103 .450 dia., feed through.	RF bypass capacitor.
H-101	—*	HANDLE, al. alloy, bent to U shape, 1/4 dia. x 3 x 3-19/32 with handle mountings blocks attached. EIL 109A1038.	Carrying Unit
H-102	—*	BLOCK, Mounting Handle, steel bent to U shape, 1/16 x 1/2 x 3/16 x 1/2 with holes and notches. EIL 109A1039.	Mounts handle
H-103	—*	HOUSING. Spare crystal.	Houses spare crystal.
H-104	—*	BOLT, Spade, steel, cadium plated, 3/4 in. lg., 8-32 thread 7/16 in. lg., 4 per unit. EIL 109A1059	Mounts rubber feet.
H-105	—*	COVER, Diaphragm, brass, irridited, gray enamel, 15/16 in. lg., 1-1/8 in. dia. EIL 109A1060.	Cap for expansion diaphragm.
H-106	—*	COVER, crystal housing, Galv. iron #26, drilled and L shaped	Cover for crystal housing.

* Not furnished as a maintenance part, If failure occurs, do not request replacement unless the item cannot be repaired or fabricated.

Ref. Designation	Navy Stock Numbers	Name and Description	Locating Functions
H-106 *(Cont.)*		for mounting. EIL 109A1030.	
J-101	–*	JACK, RF Connector, Female, type N. part of dummy load voltmeter housing A-101. Hermetically sealed. EIL 109A1032.	RF input to load
M-101	N17-M-36512-3521	METER, DC microameter, 200 microamps, 66 millivolts, 3-1/2 in., style no. 15. MBCA Ref. dwg. Group 27. Special scale, 0-15 watts, 0-60 watts. Hermetically sealed, ruggedized. CAVK Model 331. EIL 109B1048.	Power indicator
R-101	–*	RESISTOR, load, RF, composition, 51.5 ohms ±2 ohms, part of A-101. Sub-assembly consists of resistor, crystal chuck and center contact of J-101. EIL-109A1026.	Wattmeter load.
R-101A	–*	RESISTOR, part of RF load resistor R-101.	Voltage tap for crystal voltmeter
R-102	N16-R-91031 1165	RESISTOR, variable, 5000 ohms ±10%, normal torque, linear	Shunt calibrating potentiometer,

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the item cannot be repaired or fabricated.

Ref. Designation	Navy Stock Numbers	Name and Description	Locating Functions
R-102 *(Cont.)*		taper, 2 watts, RA20A1SA502AK. CTC.	60 watt scale.
R-103	N16-R-91291 4985	RESISTOR, variable 10,000 ohm ±10% normal torque, linear taper, 2 watts RA20A1SA103AK.	Shunt calibrating potentiometer, 15 w scale.
R-104	N16-R-91291 4985	RESISTOR, variable, same as R-103.	Series calibrating potentiometer, 15 w. scale.
R-105	N16-R-91291 4985	RESISTOR, variable, same as R-103	Series calibrating potentiometer 60 w. scale
R-106	N16-R-49923 231	RESISTOR, fixed, composition, 1,000 ohms ± 10%, 1 watt. RC30BF102K.	Reduces meter sensitivity.
S-101	N17-S-72018 7719	SWITCH, toggle, SPDT ST12D CHH	Scale selector switch
W-101	G15-C-10595	CABLE, DC meter, shielded, vinyl jacket. 25 ft. lg.,	DC connection to meter
CR-101	N16-T-51782	CRYSTAL, rectifier, silicon diode, type 1N82. CHS EIL 109A1041.	RF rectifier.
CR-102	N16-T-51782	CRYSTAL, same as CR-101.	Spare crystal

TABLE 6-3. CROSS REFERENCE PARTS LIST

Jan Designation	Key Symbol
RA20A1SA502AK	R-102
RA20A1SA103AK	R-103
RA20A1SA103AK	R-104
RA20A1SA103AK	R-105
RC39BF102K	R-106
ST12D	S-101
Army–Navy Type	**Key Symbol**
CY1135A/U	A-107

TABLE 6-4. LIST OF MANUFACTURERS

Prefix	Name	Address
AIRW	Atlantic India Rubber Works, Inc.	571 West Polk Street Chicago 7, Illinois
CAN	Sangamo Electric Company	11th & Converst St. Springfield, Illinois
CTC	Chicago Telephone Supply Co.	Elkhart, Indiana
CHS	Sylvania Electric Products, Inc.	Emporium, Pa.
CBRP	Electro Impulse Laboratories, Inc.	62 White Street Red Bank, N. J.
CAVK	Burlington Instrument Company	4th & Valley Street Burlington, Iowa

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